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Study on Structure Optimization of Lap Region between Skirt and Composite Case

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Abstract

To optimize Lap Region between the Skirt and Composite Case(LRSC) in Solid Rocket Motor,made finite element analysis for the load and deformation of this structure under axial compression load,proposed three optimization scheme for the LRSC,took analysis and comparison with the original design.The results show that:The layer out of skirt is the weakest link of LRSC;The maximum axial stress and capacity of the layer out of skirt decides how big is the capacity of LRSC;Spread the carbon cloth outside the elastic layer and flush with the skirt tip,could greatly reduce the axial stress of the layer out of skirt, increase the carrying capacity of composite cases.

*Keywords:*SRM;LRSC;composite case;lap length;optimization

1. Introduction

Lap Region between the Skirt and Composite Case(LRSC) of the solid rocket motor is an important link of the design. Tests prove that,with the axial compression loading,the LRSC of composite case is often the first damage, and cause failure of the whole case.With the continuous improvement of engine overload, stress distribution in LRSC and carrying capacity are more attention by designers.

At present, studies for LRSC were carried out very little,and there was no whole calculation or analysis study for LRSC.Reference[1] using three-dimensional finite element model simulated the failure mode of case under axial compression load,pointed out that compression failure of layer out of skirt due to the large axial stress was the main reason for failure of LRSC,put forward the local reinforcement measures.

Reference[2] based on the model of reference[1],studied the influence made by reinforcement and material of layer out of skirt for the capacity of LRSC,but did not make detailed simulation on

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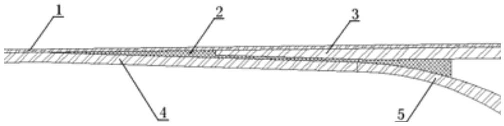
deformation of the layer.This article was based on the finite element method,calculated and analyzed the deformation of the lap under axial loads, put forward ways to optimize LRSC for improving the carrying capacity of it.

2. Model and boundary conditions

This paper based on the finite element method,did the finite element simulation by MSC.Marc software.

2.1. Finite element model

This paper based on the finite element method,did the finite element simulation by MSC.Marc software. The finite element model is shown in Fig.1.In this paper,four nodal- quadrilateral element was used to mesh the composite case.The composite material was calculated as a homogeneous orthotropic one.



1-layer out of skirt;2-rubber;3-skirt;4-winding layer inside skirt;5-head

Fig.1 The chart of LRSC

2.2. Boundary conditions

This paper simplified the case of SRM as a axisymmetrical model,analysed the LRSC of back skirt,did not consider the debonding situation,constrainted the axial displacement of case, exerted 500kN axial load on the skirt side.

2.3. Structural design and numerical calculation

Currently, the common structure of LRSC of composite case is shown in Fig.1.Carried out the finite element analysis,extracted nodal physical quantities of paths of winding layer inside skirt,tip of skirt,and layer out of skirt,as shown in Fig.2.Got the physical quantities along the path curves,as shown in Fig.3.

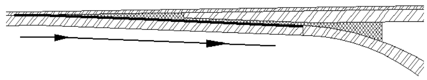


Fig.2(a)The path inside the winding layer inside skirt

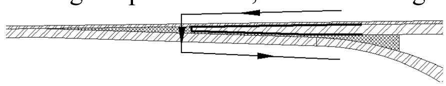
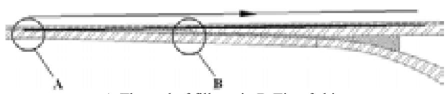


Fig.2(b)The path of tip of skirt



A-The end of fill on tip;B-Tip of skirt

Fig2.(c) The path inside the layer out of skirt

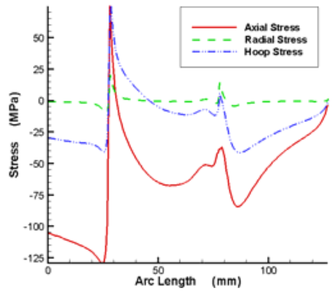


Fig.3(a)Stress of winding layer inside skirt

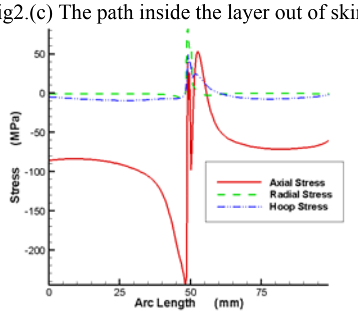


Fig.3(b)Stress of tip of skirt

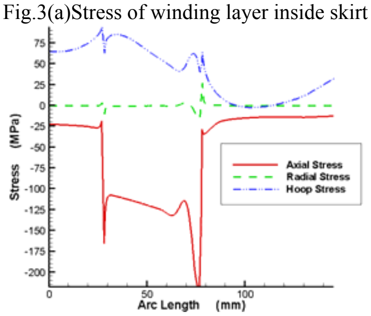


Fig.3(c) Stress of layer out of skirt

Fig.3 shows that the size of axial stress is most prominent and changes most significantly.The radial stress of winding layer inside skirt and layer out of skirt is very small,the radial stress of tip of skirt is very big. Layers inside skirt and out of skirt both have stress concentration on the end of tip,the stress of concentration in layer out of skirt is compressible,and the stress of concentration in winding layer inside skirt is tensile.Compare numerical size of stress,the axial stress in the layer out of skirt is the most prominent,the deformation of layer out of skirt is the most dramatic.Because the axial compressive strength of layer out of skirt is smaller, therefore it is prone to axial compression failure.The calculation results explained the axial failure of composite case.

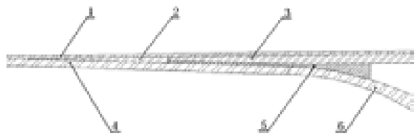
3. Structure optimization and calculation

3.1. Structure optimization

Take an example of a composite case for one model SRM,by changing the Structure of LRSC,improve the stress distribute of layer out of skirt,propose three kinds of structure,as seen in table 1 ang Fig.4. Used finite element method to calculate the stress and three ,the deformations of structure are shown in Fig.5,Fig.6, Fig.7 and Fig.8.

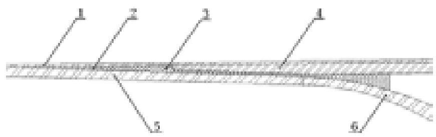
Table 1 Structure optimization of LRSC

	Structural alterations	Advantages envisaged	Remarks
1st Structure	Replaced the fill of original structure by carbon cloth in tip of skirt	Improve stress distribute of layer out of skirt	Three structures are based on the original design structure， there are no changes to other parts of the case
2nd Structure	Replaced the fill of original structure by carbon cloth in tip of skirt partly	Improve stress concentration of winding layer inside skirt	
3th Structure	Lay carbon cloth inside the layer out of skirt	Improve stress distribute of layer out of skirt	



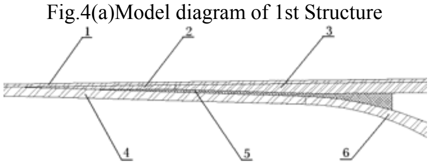
1-layer out of skirt;2-carbon cloth;3-skirt;4-winding layer inside skirt;5-rubber; 6-head

Fig.4(a)Model diagram of 1st Structure



1-layer out of skirt;2-carbon cloth;3-rubber;4-skirt;5- winding layer inside skirt;6-head

Fig.4(b)Model diagram of 2nd Structure



1-layer out of skirt;2-carbon cloth; 3-skirt;4- winding layer inside skirt;5-rubber;6-head

Fig.4(c)Model diagram of 3th Structure

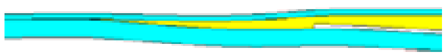


Fig.5(a)Deformation of 1st Structure

Fig.5(b)Deformation of 2nd Structure(8 times)

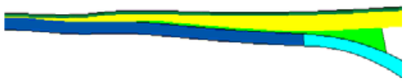


Fig.5(c)Deformation of 3th Structure(10 times)

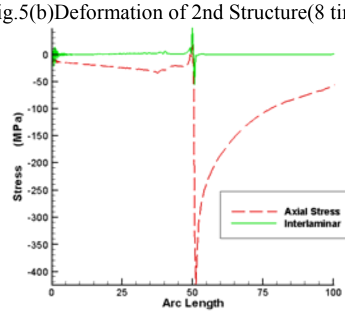


Fig.6(a) Axial stress of carbon cloth-skirt for 1st Structure

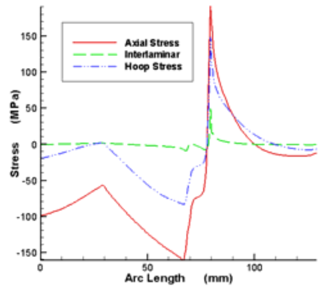


Fig.6(b) Axial stress of winding layer inside skirt for 1st

Structure

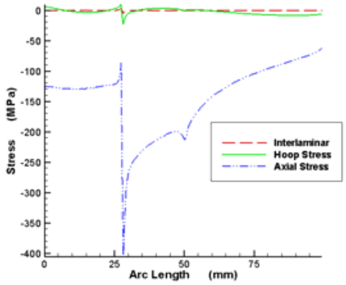


Fig.7(a) Axial stress of carbon cloth-skirt for 3th Structure

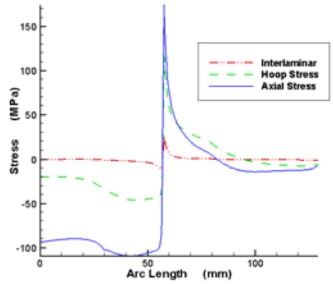


Fig.7(b) Axial stress of winding layer inside skirt for 3th Structure

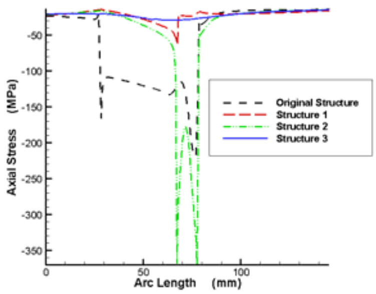


Fig.8(a) Axial stress of layer out of skirt

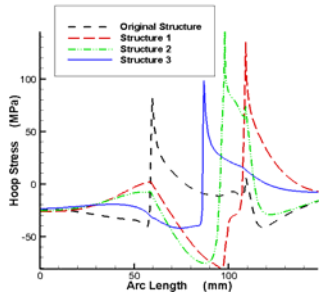


Fig.8(b) Radial stress of layer rinside skirt

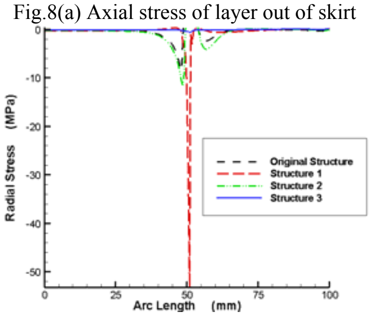


Fig.8(c) Radial stress on inter laminar of skirt

3.2. Finite Element Analysis

1st Structure,deformation of LRSC is mainly characterized by inward deformation trend.Compared with layer out of skirt,carbon cloth and winding layer inside skirt have a bigger axial modulus,because carbon cloth bears the main axial load,and transfers the axial load to winding layer inside skirt quickly.For the force of tip of skirt on carbon cloth and winding layer inside skirt is inclined to one side of section,and the force of skirt on winding layer inside skirt is counterclockwise rotation moment, bending the skirt inward.

The axial stress of layer out of skirt is much smaller than the one of original structure.The structure is not prone to compression failure.Carbon cloth bears axial load and bending moment,its axial stress at the edge and interlaminar stress is larger.The axial compressive strength of carbon cloth is very large and interlaminar tensile strength is very small.Compared with the stress distribution here, the axial stress of carbon cloth is not big,and interlaminar stress is too big,which lead to delamination failure of the carbon cloth.

1st Structure avoids the defects of damage on layer out of skirt in the original design structure, skirt and winding layer inside skirt of LRSC are prone to delamination,the carrying capacity of LRSC is not improved,compared with the original design structure, replaces the carbon cloth with the rubber which has small density,the 1st Structure will have an inertia large quality than the original design structure.

2nd Structure,layer out of skirt has a bigger deformation,a larger extreme axial stress and a stress concentration.The carbon cloth replaced the fill in the end of skirt tip bears larger interlaminar stresses,it will be prone to delamination.The delamination would quickly lead to the crack damage between layer out of skirt and winding layer inside skirt.The winding layer inside skirt bears uniform stress,it will be not prone to damage.

The layer out of skirt and carbon cloth are prone to damage in the 2nd Structure,which has a lower structural strength and increases the inertia quality of LRSC.

3th Structure,the layer out of skirt always coats on carbon cloth outside,which bears smaller axial stress and is not prone to compression failure. Although the carbon cloth and skirt bear a greater axial compression,for carbon cloth has a higher axial compression strength,it will not be prone to compression failure.The winding layer inside skirt has a large mutations of axial stress and risk of a delamination. 3th Structure solves the defect of layer out of skirt in the original design structure,the carrying capacity of LRSC will be improved obviously.But compared with the original design structure, the inertia quality of 3th Structure is larger.

It can be seen by comparing, the original design structure has a higher carrying capacity,good technology, better overall performance, broader scope of application.Compared with the original design structure,the 1st Structure needs not to separate processing of rubber,removes assembly difficulties,has a simple technology process. But its carrying capacity has not been improved,and its inertia quality is larger.The 2nd Structure has a more simple technology process,but a lower carrying capacity and a larger inertia quality.The 3th Structure has a more complex technology process,a larger inertia quality,but a higher carrying capacity, and would be applicable for SRM with greater axial load.

4. Conclusion

a.Through the finite element simulation of LRSC,analysed the deformation and stress distribute of composite case,explained the axial compression failure modes of composite case.

b.In the axial compression load,layer out of skirt of LRSC bears bigger axial compression,axial stress will be larger.The layer is prone to compression failure,leading to failure of LRSC.Extreme axial stress and carrying capacity of layer out of skirt determine the carrying capacity of LRSC.

c.Proposed three optimization solutions, analyzed and compared with the original design structure. The results show that,the original design structure has a better overall performance of LRSC,but a lower carrying capacity, and would not be applicable for SRM with greater axial load.The 3th Structure a higher carrying capacity of LRSC,and would be applicable for SRM with greater axial load.The 1st Structure has a simple technology process,is easy to form,but has a lower carrying capacity,would be applicable for SRM with lower axial load.Section headings should be left justified, with the first letter capitalized and numbered consecutively, starting with the Introduction. Sub-section headings should be in capital and lower-case italic letters, numbered 1.1, 1.2, etc, and left justified, with second and subsequent lines indented. You may need to insert a page break to keep a heading with its text.

References

[1]Bing Wang,Luxian Wang,Xiao Hou,Yuanchong Zhang.Numerical analysis of local reinforcement of composite case under complicated load[J].JOURNAL OF SOLID ROCKET TECHNOLOGY,2004,27(3),216-219.

[2]Hongyu Xu,Yanshuang Wang,Dianyun Chen,ect. Analysis of Failure and Optimization for Composite Case of Solid Rocket Engine[J].JOURNAL OF HENAN UNIVERSITY OF SCIENCE & TECHNOLOGY,2005,26(4),8-11.